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(54) A method of and apparatus for trenching.

(57) Apparatus for producing a trench in an irregular terrain comprising a plough having plough shares (10) and supporting skids (5). Control means control the distance between shares and skids to control the trench depth (D). The terrain is surveyed along the intended trench route and information from the survey is fed to the control means enabling the plough to react to irregularities in terrain in advance to reduce the effect of those irregularities. Thus, for example, the variation in trench profile may be spread over a longer distance (L_1) to reduce the impact of a hump of height (H) in the terrain. This in turn reduces the possibility of upheaval buckling of a flowline placed in the trench.

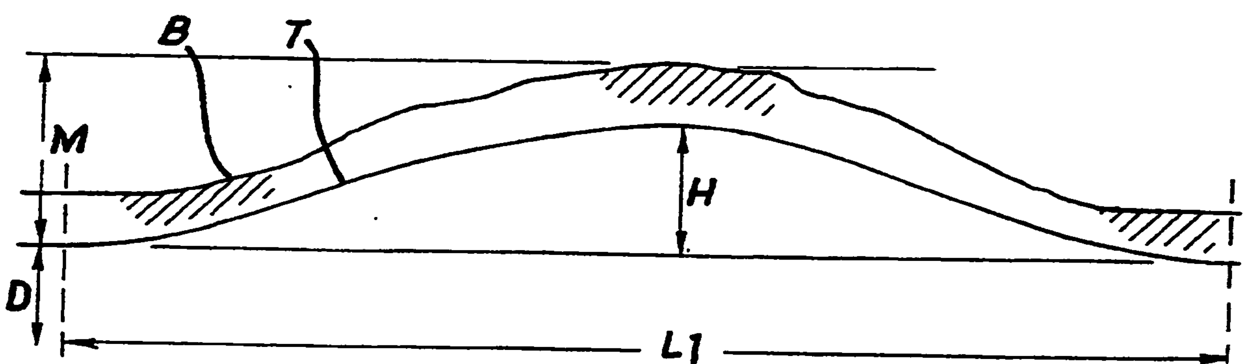

FIG.5

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The present invention relates to a method of and apparatus for trenching.

Trenching is a particularly viable option for protecting the small but hot flowlines which are being laid in current North Sea developments. Such flowlines are prone to upheaval buckling due to the large compressive forces which arise from high operationg temperatures. The flowlines are usually restrained from upheaval buckling by a continuous rock cover at a specified height above the top of the flowline. There are two main advantages of trenching for such flowlines. Firstly, the volume of rock required to provide adequate cover is reduced if the flowline is first placed in a trench. Secondly, the process of trenching will tend to flatten out upwards imperfections or 'humps' in the sea bed profile. Upheaval buckling is known to be very sensitive to the size of such imperfections. Trenching can therefore help to achieve the required overbend imperfection sensitivity level.

Existing ploughs for trenching are able to reduce the height of sea bed imperfections due to the beam, or distance between front skids and shares of the plough. In normal operation, the plough can only cut a trench to a constant depth below the sea bed. When a change in sea bed profile is reached, the beam prevents the plough from responding immediately to the change in profile. When a 'hump' is reached, the plough will temporarily cut a deeper trench before responding to the change in sea bed depth, and so will cut a trench with a lower imperfection height than the sea bed. A similar effect takes place for a 'hollow' in the sea bed, where the plough will cut a shallower trench and will again cut a smoother trench than the sea bed. After a short distance the plough will have responded to the change in sea bed depth, and will return to cutting the same constant depth of trench. Existing ploughs are therefore beneficial towards preventing upheaval buckling, particularly if the plough is of a 'long beam' design, but can only do so to a limited degree.

According to one aspect of the present invention there is provided a method of producing a trench in an irregular terrain including the steps of progressively moving trench producing apparatus over the terrain in order to produce a trench in that terrain, adjusting the trench depth of the trench producing apparatus ahead f or at an irregularity in order to reduce the effect of that irregularity on a flowline placed in the trench.

According to another aspect of the present invention, there is provided apparatus for producing a trench in an irregular terrain comprising trench producing means disposed for insertion into the surface of the terrain, means for supporting the apparatus above the trench to be produced, means for adjusting the relative positi n f the means for supporting and means for producing to enable trench d pth to be varied and control means for adjusting the relative postion ahead of or at irregularities in the surface.

In a preferred embodiment the apparatus comprises a plough, the means disposed for insertion comprise on or more plough shares, the means for supporting comprise skids, and the means for adjusting enable the distance between share(s) and skids to be altered. The skids and share(s) are attached to a plough beam.

The control means effectively gives the apparatus intelligence. The ideal profile at the bottom of the trench is perfectly flat and level. This is quite feasible for a plough which can adjust its cutting depth as it moves along the pipeline. However, it will not b possible to achieve a perfectly flat trench bottom if th variation in sea bed profile exceeds the available change in share setting. Under such circumstances it is desirable to know the variation in sea bed profile ahead of the plough, so that the 'severity' of any imperfections can be limited. If the plough can react to expected imperfections well in advance, then the maximum severity of the imperfection can be greatly reduced.

For example, a simple plough which adjusts its cutting depth according to an instantaneous sea bed profile would not react to a large upwards imperfection until the required trench depth was less than the share setting depth. The plough would then follow the sea bed profile until the required trench depth was less than the maximum cutting depth. In contrast, if the plough could react to the imperfection in advance, then the trench depth could be controlled to give a smooth trench bottom profile over the imperfection.

Assuming that the variation in sea bed profile exceeds the available change in plough cutting depth, a criteria for the desired profile must then be determined. This can be calculated on the basis of the overbend imperfection sensitivity.

Upheaval buckling is dependent on the height of upwards imperfections, or 'humps' in the profile on which the pipe rests. In comparison, downwards imperfections are of relatively little importance. A hot flowline will tend to sag down into such an imperfection, and will not affect upheaval buckling unless buckling is possible on either side of the sag. The required profile at the bottom of the trench will therefore have the minimum number of, and lowest, upwards imperfections. A limit on downwards imperfections will exist, such as on the basis of maximum bending criteria or local buckling in the sag. However, this limit may not be reached if the smoothing action of the plough beam prevents the cutting of such sharp imperfections.

Provided that accurate survey information of the proposed route is available, the required trench b t-tom profile can be calculated on th basis of the criteria above.

From the plough geometry the required plough share depth settings can then be determined in terms of the plough position along the flowline. The plough

can th n be operated by controlling the share depth at any distance along the flowline according to this predetermined share depth.

This is the basis of the plough operation. In practice, if the plough deviates from the required trnech depth then instrumentation will determine how the plough should return to the original specified trench depth. This will be achieved by monitoring the plough status from a support vessel. Transducers will record plough status in XYZ axes. In operation this input will be monitored and compared against the initial or expected plough status. The required share settings can then be updated on this basis and revised plough settings will be displayed and passed on to the plough itself.

In order that the invention may be more clearly understood, embodiments thereof will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 shows a plan view of a trench producing plough,

Figure 2 shows an end elevational view of the plough of Figure 1,

Figure 3 shows a side elevational view of the plough of Figure 1,

Figure 4 diagrammatically shows a sea bed trench with a "small" sea bed irregularity produced in accordance with the invention,

Figure 5 diagrammatically shows a sea bed trench with a large sea bed irregularity produced in accordance with the invention, and

Figure 6 diagrammatically shows a sea bed trench produced in accordance with the prior art for the terrain shown in Figure 5.

Referring to Figures 1 to 3, the structure is in three parts hinged together high up above and beside the pipe. It comprises front and rear pipe supports 1 and 2, steering arms 3, steering linkages 4, skids 5, a tow bridle 6, share opening cylinder 7, control and hydraulics package 8, lift point 9 four cutter 10 and pipe grab assembly 11. The plough is opened and closed by hydraulic rams above the hinges to permit lifting and lowering of the pipe. When the two lower parts of the plough are closed they lock together to form a single integrated structure. The structure of the plough beams places them either side of the pipe rather than over or under it. The main front structure bridges over the pipe with a large clearance above it to permit the plough to sink when encountering pipe spans. This bridge is placed near the centre of the plough so that it can pitch through a large angle.

The main towing forces are transmitted directly into the front of each of the beams and are carried down th sl ping shields under the pipe and into th plough shares at ground level. This results in low beinding moments being applied to th beams.

The two plough shares lock together when they close so that all ploughing forces are shared by the two beams.

Th plough supports the pipe on widely separated support rollers at the front and rear of the pl ugh. This dual support is necesary if smaller pipes are not to be overstressed.

The high clearance above the pipe and the central positioning of bridging structure permits the plough to pitch 9 degrees either way with a 12 inch pipe. This is increased for smaller pipes. When the plough pitches, the support on the pipe is maintained by adjusting the elevation of one set of rollers. This is done automatically by the plough hydraulic system.

The high clearance and good pitch capability enables large pipes with piggy backed small pipes n their top sides to be safely trenched. The pipe is lifted up into the plough by separate pipe lifters.

The vertical and sideways forces between pipe and plough are measured by load cells in the roller cradles. The vertical pipe forces vary from 24 tones for a heavy concrete 36 inch pipe, to less than 1 tonne for a 6 inch epoxy-coated pipe. In order that these forces can be measured accurately and the automatic constant suport system work properly, a range of different pipe suport links, rollers, hydraulic cylinders and load cells are provided.

The plough is fitted with a steering system. Steering arms on either side of the plough can be driven backwards and forwards by two hydraulic cylinders. A linkage between the arms keeps them in a proper relationship and minimises the power required from the hydraulic cylinders. The ends of these arms are connected to the ends of a triangular bridle, which is itself connected to the two rope.

Movement of the arms has the effect of moving the apex of the bridle sideways across the front of the plough.

If the apex is shifted to one side, then the tow force makes a couple and this causes the plough to rotate rapidly into the position where the coupl is reduced to zero. The plough then moves outwards relative to the track of the ship until it comes into equilibrium. By this means the plough can be steered along the pipe independently of the track of the ship (within limits). The steering is under continuous manual control and the operator seeks to maintain zero lateral force on the pipe at the front rollers.

Alternatively with the steering locked the plough can be steered by using the towing vessel alongside the correct track.

The plough is fitted with thrusters foe and aft which enable it to be rotated and shifted sideways to locate on the pipe. This is facilitated by the wide gap between the shares and pipe lifter jaws in the open position.

The plough is lifted from the single lift point 9 high up above its centre of gravity. The recovery system includes a plough mounted hydraulically operated winch which renders to release a buoy and

messenger/haul down line. The buoy is recovered on surface and the main lift line and latch pin returned to the plough by hauling down with the hydraulic winch under constrant tension.

Examples of the plough in operation will now be described with reference to Figures 4, 5 and 6.

Figure 4 shows the position of the trench T with a "small" sea bed irregularity. As the sum of the maximum height M of the irregularity over the normal plane P of the sea bed and the depth D of the trench is less than the maximum trench depth which the plough can accommodate, the trench may remain horizontal as shown.

Figure 5, shows the position of the trench T with a large sea bed irregularity. As the sum of the maximum height M of the irregularity over the normal plane P of the sea bed and the depth D of the trench exceeds the maximum trench depth which the plough can accommodate, the trench must follow the profile of the irregularity to a certain extent. As, in accordance with the invention, the plough is aware of the approaching irregularity steps can be taken to minimize the abruptness with which the contour of the trench is changed. Thus, as compared with the trench of Figure 6, which shows the conventional trench position for the same irregularity, the variation in the trench contour is spread over a greater distance by reducing the trench depth at the beginning B of the irregularity. As a result the ratio between the maximum contour height variation H and the distance L_1 or L_2 over which this occurs is less in Figure 5 than in Figure 6. i.e. $\frac{H}{L_1} < \frac{H}{L_2}$

The trench depth is altered by changing the height of the shares relative to the front skids of the plough. This is controlled from a support vessel while the plough is in operation. By varying the trench depth as the plough moves along the pipeline, any imperfections can be significantly reduced. As an increase in sea bed level is reached, the share setting will be increased, the plough will cut a deeper trench through the 'hump' and a smooth level trench will result. If any 'hollows' are encountered in the sea bed, then the plough will cut a shallower trench through the hollow, and will cut a level trench again. With appropriate control, the 'smart' plough can achieve the specification for overbed imperfection sensitivity, and to a much greater extent than existing ploughs.

It will be appreciated that the above embodiments have been described by way of example only and that many variations are possible without departing from the scope of the invention.

Claims

1. Apparatus for producing a trench in an irregular terrain comprising trench producing means disposed for insertion into the surface of the terrain, means for supporting the apparatus above the trench to be produced, means for adjusting the relative position of the means for supporting and means for producing to enable trench depth to be varied and control means for adjusting the relative position ahead of or at irregularities in the surface.

2. Apparatus as claimed in claim 1, in which the means disposed for insertion comprises one or more plough shares.

3. Apparatus as claimed in claim 1 or 2, in which the means for supporting comprise skids.

4. Apparatus as claimed in claim 1, 2 or 3, in which the means for adjusting enable the distance between share(s) and skids to be altered.

5. Apparatus as claimed in any preceding claim, in which the control means is programmed with information relating to irregularities to be encountered and is operative to adjust the relative position of the means for supporting and the means for producing over a greater length of trench whereby to reduce the rate of change of trench depth with length of trench whereby to reduce the abruptness of changes in trench profile.

6. A method of producing a trench in an irregular terrain including the steps of progressively moving trench producing apparatus over the terrain in order to produce a trench in that terrain, adjusting the trench depth of the trench producing apparatus ahead of or at an irregularity in order to reduce the effect of that irregularity on a flowline placed in the trench.

7. A method as claimed in claim 6, in which the terrain is surveyed along the proposed route of the trench to be cut.

8. A method as claimed in claim 7, in which control means for controlling the operation of the trench producing apparatus is fed with information relating to irregularities in the terrain obtained from the survey to enable it to adjust the trench producing apparatus ahead of those irregularities whereby to reduce the abruptness of changes in trench profile.

9. A method as claimed in claim 6,7 or 8, in which the status of the apparatus is monitored during a trench cutting operation and compared with the expected status.

10. A method as claimed in claim 9, in which plough share settings are updated on the basis of information obtained from the comparison.

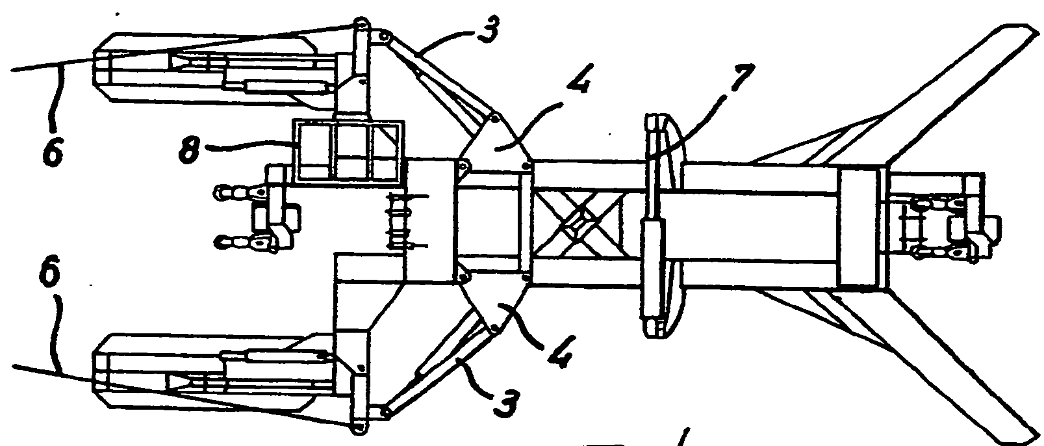

FIG. 1

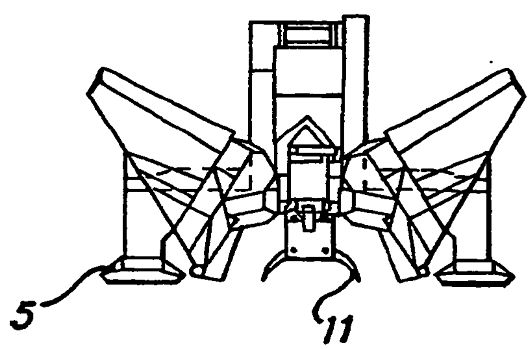

FIG. 2

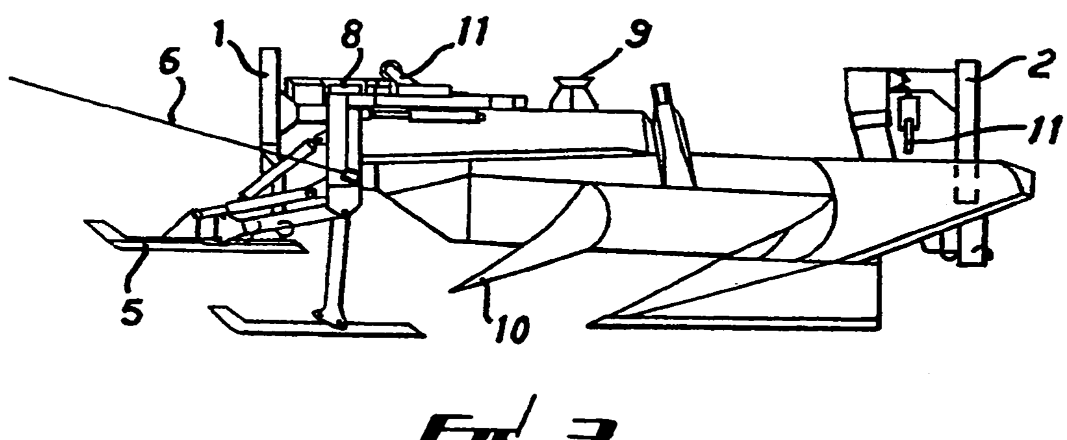

FIG. 3

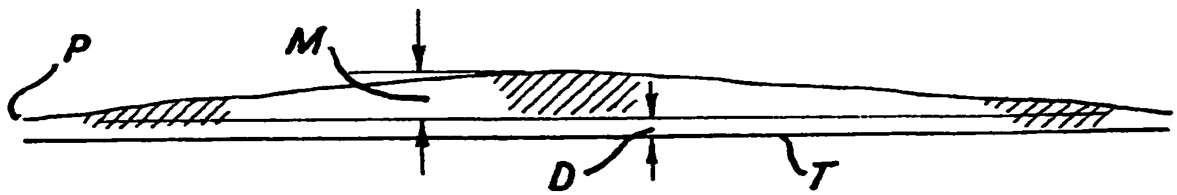

FIG. 4

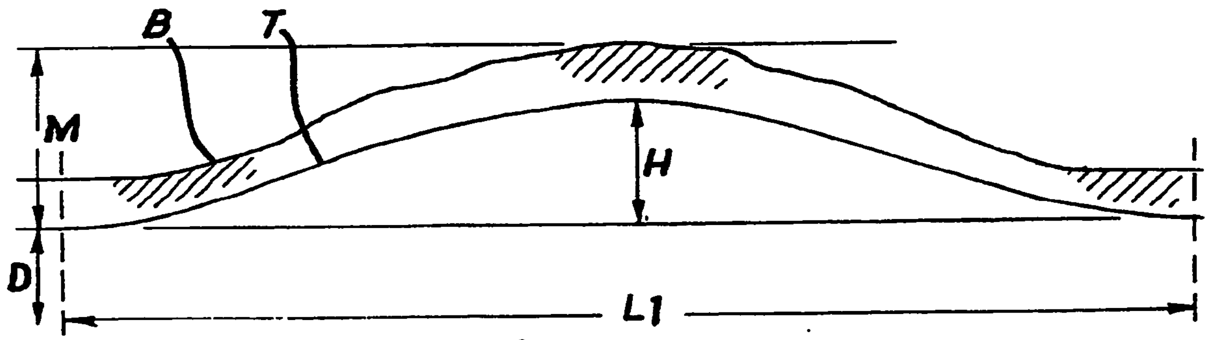

FIG. 5

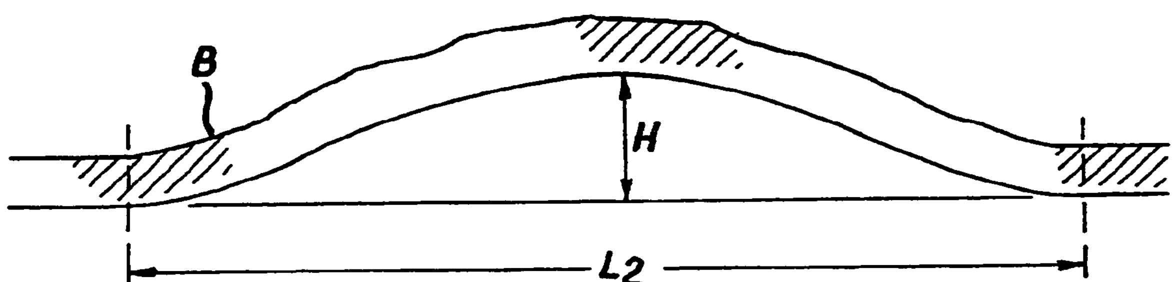

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number

EP 91 30 2887

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	GB-A-1 107 303 (THE RANK ORGANISATION LTD) * The whole document * ---	1-10	E 02 F 5/10 E 02 F 5/14
X	FR-A-2 506 114 (PELSY) * The whole document * ---	1-10	
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X	GB-A-1 015 160 (VEB WEIMAR-WERK) * The whole document *	1,2	
A	---	5-10	
X	GB-A- 748 086 (T. COOPER) * Page 1, lines 36-91; figures 1-4 *	1-3	
A	-----	5-10	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			E 02 F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	02-07-1991	ANGIUS P.

CATEGORY OF CITED DOCUMENTS

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